Discovery of a Group of Star-Forming Dwarf Galaxies in Abell 1367

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ABSTRACT

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We describe the properties of a remarkable group of actively star-forming dwarf galaxies and H II galaxies in the Abell 1367 cluster, which were discovered in a large-scale Hα imaging survey of the cluster. Approximately 30 Hα-emitting knots were identified in a region approximately 150 kpc across, in the vicinity of the spiral galaxies NGC 3860, CGCG 97-125 and CGCG 97-114. Follow-up imaging and spectroscopy reveals that some of the knots are associated with previously uncataloged dwarf galaxies ($M_B = -15.8$ to -16.5), while others appear to be isolated H II galaxies or intergalactic H II regions. Radial velocities obtained for several of the knots show that they are physically associated with a small group or subcluster including CGCG 97-114 and CGCG 97-125. No comparable concentration of emission-line objects has been found elsewhere in any of the eight northern Abell clusters surveyed to date. The strong Hα emission in the objects and their high spatial density argue against this being a group of normal, unperturbed dwarf galaxies. Emission-line spectra of several of the knots also show some to be anomalously metal-rich relative to their luminosities. The results suggest that many of these objects were formed or triggered by tidal interactions or mergers involving CGCG 97-125 and other members of the group. A Westerbork Synthesis Radio Telescope HI map of the region shows direct evidence for tidal interactions in the group. These objects may be related to the tidal dwarf galaxies found in some interacting galaxy pairs, merger remnants, and compact groups. They could also represent evolutionary precursors to the class of isolated ultracompact dwarf galaxies that have been identified in the Fornax cluster.

Subject headings: galaxies: dwarf – galaxies: formation – galaxies: evolution – galaxies: clusters: individual (Abell 1367)

1. INTRODUCTION

Until recently most surveys for star-forming galaxies in the nearby universe have been restricted to imaging of previously cataloged objects, or wider-field prism surveys that are mainly sensitive to strong emission-line galaxies. These have provided a relatively complete inventory of massive galaxies and starburst galaxies, but they provide much less complete information on the population of star-forming dwarf galaxies. Large numbers of very nearby star-forming dwarfs have been studied (e.g., Terlevich et al. 1991, Hunter, Hawley, & Gallagher 1993, van Zee 2000, 2001), but complete star formation inventories, extending across the full range of galaxy types *and* masses, are lacking.

As part of a larger effort to obtain complete inventories of star formation rates (SFRs) in nearby galaxy samples, we have carried out a deep, wide-field Hα survey of nearby clusters of galaxies using the MOSAIC CCD camera on the 0.9 m telescope at Kitt Peak National Observatory (Sakai et al. 2001a). Each field covers one square degree, and we have obtained high-quality data for 25 fields in 8 nearby northern Abell clusters, in the radial velocity range $3000 - 8000$ km s^{-1}. A total of six fields were observed in Abell 1367, and $\sim$250 Hα-emitting galaxies were detected (Sakai et al. 2002, in preparation). During the course of this analysis we discovered an unusual concentration of Hα-emitting dwarf galaxies and H II galaxies in the central field of the Abell 1367 cluster. A brief report was given in Sakai et al. (2001b). Recently Iglesias-Paramo et al. (2002) presented the results of an independent Hα survey of the center of A1367, and they comment specifically on the unusual properties of this region of the cluster (see the appendix of their paper). Our follow-up spectroscopy (§4) shows that these objects are part of a low velocity dispersion group or subcluster within or behind the main cluster, which also contains two Zwicky galaxies: CGCG 97-114 and CGCG 97-125.

Although the discovery of emission-line dwarf galaxies in Abell 1367 is not extraordinary in itself, the concentration of such objects in this region is very unusual — to date no other such concentrations have been found in any of the eight clusters we surveyed. Moreover, emission-line spectra obtained for several of the knots reveal chemical properties that are inconsistent with the scenario that this region is simply a grouping of normal star-forming dwarf galaxies. Instead, the observational evidence suggests that at least some of the objects are the products of galaxy interactions or other environmental processes within the group, or in conjunction with the larger A1367 cluster. Consequently this serendipitously discovered group may offer valuable clues to the physical processes that influence the evolution and formation of dwarf galaxies in groups and clusters.

The remainder of the paper is organized as follows. In §2 we discuss the data collected on this region, including the Hα and follow-up broadband imaging, emission-line spectroscopy, and HI aperture synthesis observations. In §3 we use these data to characterize the nature of the galaxy group and measure the SFRs and basic physical properties of the star-forming dwarfs. Finally in §4 we consider possible physical explanations for the nature and formation of these objects, and tentatively conclude that they are a combination of pre-existing dwarf galaxies, intergalactic HII regions, and possibly newly formed dwarf galaxies, all triggered by tidal interactions between the larger members of the group. We also place these results in the context of other discussions of tidally-formed dwarf galaxies (e.g., Mirabel, Dottori, & Lutz 1992), and H II regions (Iglesias-Paramo & Vílchez 2001), and the recent discovery of compact blue galaxies in the Fornax cluster (Drinkwater et al. 2001, Phillips et al. 2001).

2. DATA

Here we briefly describe the wide-field MOSAIC Hα imaging in which the objects were discovered, and which have been used to quantify the star formation properties of the group members. In addition we describe follow-up optical imaging, spectroscopy, and HI observations, which were obtained in an effort to understand the physical nature and formation of the dwarfs.

2.1. MOSAIC Imaging

The Hα images were obtained under photometric conditions in 1999 Feb, using the MOSAIC-1 camera on the KPNO 0.9m telescope. The camera is comprised of eight 2048$\times$4096 SITe CCDs with 15μ pixels, corresponding to 0.43$''$/pixel, and a total aereal coverage of 59$'$ $\times$ 59$'$ on the sky. The observation of the central field of Abell 1367 was centered at ($11^h44^m09^s$,19°52$'$33$''$) (J2000). Each observation consisted of five dithered 900 s exposures, using three filters centered at 6615 Å (Ha4), 6695 Å (Ha12), and 6736 Å (Ha16). The effective bandwidth of each filter is approximately 80 Å. Since the mean velocity and velocity dispersion of Abell 1367 are 6595 km s^{-1} and 879 km s^{-1} respectively (Struble & Rood 2001), two on-band filters (Ha12, Ha16) were used for the detection of Hα emission, and Ha4 for the continuum observation. For most galaxies the filters admitted the adjacent [NII] lines at 6548 Å and 6583 Å as well, and for the purposes of this paper we will use "Hα" to refer to the combined Hα+[NII] emission.

The raw images were processed within the NOAO IRAF package[3], using standard procedures as documented in the NOAO MOSAIC manual (available on-line at URL: http://www.noao.edu/kpno The flatfield correction for each filter was made by taking a median of five dome flats, which was sufficient for these narrowband images. Two extra steps needed to be performed with the reduction of the MOSAIC images, compared to conventional single-detector cameras, in order to correct for the variable pixel scale, which changes by 6% from the center to the edge of the field. The dithered images were reinterpolated to a tangent-plane projection, to provide a constant angular scale. The typical image quality on the combined and regridded images, set by seeing and the reinterpolation process, is approximately 1.3$''$ FWHM.

The flux zeropoints for the emission-line images were calibrated using observations of

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[3]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

spectrophotometric standards from Massey et al. (1988), and analyzed using standard techniques for narrowband images (e.g., Kennicutt & Kent 1983). The 75 min combined exposures provide 5-σ emission-line detections of extended sources to approximately 10^{-15} ergs cm^{-2} s^{-1}, which corresponds to an absolute luminosity of $\sim 10^{39}$ ergs s^{-1}, or a total SFR of $\sim$0.01 $M_{\odot}$ yr^{-1}, using the calibration of Kennicutt (1983). The detection limits for single, compact H II regions are approximately an order of magnitude fainter.

2.2. Deep Imaging

Most of the faint objects discovered in the Hα images have not been cataloged, and for many of them no continuum counterparts were visible on the MOSAIC camera red continuum images described below. In order to identify any faint parent galaxies associated with any of the objects, and measure their basic photometric properties, we obtained follow-up deep B and R imaging in February 2001. The data were obtained using the 2KCCD imager on the Bok 2.3 m telescope at Steward Observatory. The camera uses a 2048×2048 thinned Loral CCD detector, which was binned 3×3 to yield $0\farcs45$ pixels and a field of view of 205 arcsec. A series of exposures were obtained in each filter, providing combined exposure times of 3600s in B and 1800s in R. Data were taken under photometric conditions, with seeing varying between $1.1'' - 1.4''$ FWHM.

We also used the same camera in March 2002 to obtain a series of deep Hα images of the region. The 2KCCD imager was used with a 75 Å FWHM filter centered at 6730 Å for the on-band image, with an accompanying R image used for continuum subtraction. Three exposures totaling 3600 sec in exposure time were obtained, yielding images about 5 times deeper (in effective exposure time) than the MOSAIC images.

The images were reduced following standard CCD reduction procedures; they were bias-subtracted and flatfielded using IRAF routines. For the broadband imaging standard stars in the RU 149 field (Landolt 1992) were observed several times during the night and were used to calibrate the photometric zero points. The Hα images were reduced using the same procedures as described in the previous section.

2.3. Emission-Line Spectroscopy

Before we could interpret the images it was important to obtain radial velocities for some of the emission knots, in order to confirm whether they were associated with Abell 1367 and to place constraints on the kinematic properties of the system. Exploratory spectra were obtained for several of the objects on four nights between April 1999 and April 2000, using the B&C CCD Spectrograph on the Steward Observatory 2.3 m Bok telescope. Although the immediate objectives were to determine radial velocities for the knots, the spectra were of sufficient quality to impose some constraints on the excitation and abundance properties of the regions as well, as discussed in the next section.

The B&C spectrograph was used with a 400 gpm grating and a 1200 × 800 thinned Loral CCD detector, which provided coverage of the spectral region 3650 – 6950 Å. A slit width of 2.″5 yielded a resolution of 7.5 Å. Observations were carried out with the galaxies near the zenith to eliminate any problems of atmospheric dispersion. Standard calibration and long-slit reduction procedures were employed, using standard stars from Massey et al. (1988) and the TWODSPEC programs in IRAF. Wavelengths of telluric night-sky lines in the spectra were used to apply a second-order zeropoint correction to the radial velocity scales.

The target H II regions were quite faint ($f(H\alpha) \sim 0.7 - 4 \times 10^{-15}$ ergs cm^{-2} s^{-1}), requiring blind offsets from nearby stars and bright galaxies, as derived from the MOSAIC images. Typical integration times were 900 – 2400 sec, sufficient to confirm the redshifts of the objects, and in some cases derive approximate line ratios for the strongest features (Hα, Hβ, [OII], [OIII], [NII]). Hα was easily the best detected line, and it was used to measure the radial velocities of the knots, with a typical measurement uncertainty of ±50 km s^{-1}. Usable spectra were obtained for seven objects (knots Dw1-a,b; Dw3-a,c; K2-a,b; CGCG 97-125-b in Figure 4). We also observed two H II regions in the main disk of the disrupted spiral galaxy CGCG 97-125, to provide a reference and to test the hypothesis that some of the intergalactic regions may have originated from gas removed from the larger galaxies.

In January 2002, spectra for four H II regions in the newly identified dwarf galaxy Dw 1 (Table 2, Figure 4) and in CGCG 97-125 were observed using the Blue Channel spectrograph on the newly refurbished 6.5 m MMT telescope. The spectrograph was equipped with a 500 gpm grating blazed at 5410 Å, and a 3072 × 1024 thinned Loral CCD detector, which provided spectra of the region 3600 − 7000 Å with a resolution of 5 Å. Pairs of H II regions in Dw 1 and CGCG 97-125 were observed in single pointings for a total exposure time of 2400 seconds. These yielded high S/N detections of the principle diagnostic emission-lines, and an independent check on the accuracy of the spectra obtained at the 2.3 m telescope. The data were reduced using the same procedures as described above.

2.4. HI Aperture Synthesis Imaging

In order to place further constraints on the origin of the dwarf galaxies and emission knots, we obtained aperture synthesis HI data using the Westerbork Synthesis Radio Telescope (WSRT). The WSRT observations were centered around NGC 3860, CGCG 97-114 and CGCG 97-125. The detailed observing parameters are given in Table 1. The velocity range covers the velocities of CGCG 97-114 and CGCG 97-125, but not the lower velocity of NGC 3860 (5595 km s^{-1}, see next section).

We used the Miriad package (Sault et al. 1995) for the editing, calibration and Fourier inversion of the data, and did the subsequent analysis in Gipsy (van der Hulst et al. 1992, Vogelaar and Terlouw 2001). The WSRT is now equipped with a new correlator and cooled 21-cm front-ends on all telescopes, so that it becomes worthwhile to use all possible telescope combinations for imaging the field of view and increase significantly the sensitivity. The final resolution of the data is a compromise between optimal sensitivity for detecting low surface brightness HI, and retaining sufficient resolution to be able to resolve the galaxies and their immediate environs.

The r.m.s. noise in the channel maps is 0.4 mJy which for the $18'' \times 50''$ resolution corresponds to a brightness temperature of 0.25 K. The corresponding 3σ detection limit in column density is 2.4×10^{19} cm^{-2}. The limiting mass for a 50 km s^{-1} wide profile is 1.9×10^{8} $M_{\odot}$.

3. RESULTS

The structure of the CGCG 97-114/125 region is illustrated in Figure 1, which shows deep B and R images of the field. In Figure 2, we show the combined Hα+[NII] image. The most prominent galaxy in the field is NGC 3860, but the radial velocity of this galaxy is offset from most of the objects in the field by 2600 km s^{-1} (5600 km s^{-1} for NGC 3860 vs $8200 - 8300$ km s^{-1} from the main group (de Vaucouleurs et al. 1991, Giovanelli et al. 1997, Haynes et al. 1997), so it probably lies in the foreground to the group. We will refer to this region as the CGCG 97-114/125 Group for convenience, based on the real physical association of these objects.

3.1. Properties of the CGCG 97-114/125 Group

The center of this group is located at ($11^h44^m50.6^s$, $19°46'56''$)(J2000). This lies at a projected distance of only $6'$ (0.2 Mpc) southeast of the center of the A1367 cluster (Abell, Corwin, & Olowin 1989). The location of the group is shown in Figure 3, which plots the spatial and velocity distributions of the galaxies in the clusters, as taken from the NASA/IPAC Extragalactic Database (NED)[4]. The approximate location of the brighter members of the CGCG 97-114/125 group is indicated by the open circle in each plot. These plots show that the group lies at the upper edge of the velocity distribution, displaced by approximately 1700 km s^{-1} from the centroid of A1367 as a whole, implying that either the group is infalling into the central core of the A1367 cluster from the foreground, or that it lies in the background to the cluster, as an extended part of the Coma-A1367 supercluster. The group spans approximately $4-5$ arcmin on the sky, which corresponds to a linear diameter of $110-130$ kpc, if we adopt the distance to A1367 of 93 Mpc from Sakai et al. (2000). If the group lies in the background at its Hubble flow distance (110 kpc for $H_0 = 75$ km s^{-1} Mpc^{-1}) the linear size would increase to $130-165$ kpc.

3.2. Identification of Dwarf and HII Galaxies

Some of the emission-line galaxies and knots in this field were immediately apparent on the raw Hα images, even before continuum removal. To obtain a more complete data set, continuum-subtracted Hα line images were obtained by shifting and scaling the Ha4 continuum images to the same scales and subtracting them from the on-band Ha16 and Ha12 images. These subtracted images were then blinked with the continuum images to identify the objects visually. All of the emission-line objects were visible only on the Ha16 image, but not on the Ha12 image (with the exception of NGC 3860). Several other faint emission-line structures were identified later on the deeper 2.3 m telescope Hα images. The objects found are indicated in Figure 4.

The galaxies and objects seen in this group fall quite cleanly into three classes: (1) previously cataloged Zwicky galaxies with multiple H II regions in their disks; (2) previously unidentified dwarf galaxies, identified in Figure 4 as $Dw1$, $Dw2$ and $Dw3$; (3) isolated intergalactic H II knots, with no detectable underlying stellar components (e.g., $K1$ and $K2$ in Figure 4). Table 2 summarizes the properties of the galaxies and Table 3 lists positions

[4]This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

and properties of the isolated H II knots.

3.2.1. Zwicky Galaxies

As described earlier, the group is defined by the galaxy pair CGCG 97-114 (also known as NGC 3860B) and CGCG 97-125, and possibly two other cataloged objects, CGCG 97-113 and A1367[BO85] 121 (Butcher & Oemler 1985). Neither of the latter two objects have published radial velocities (NED lists a velocity of 6413 km s^{-1} for CGCG 97-113 but no source is given), so their physical association with this group is uncertain.

CGCG 97-114 and 97-125 are luminous galaxies ($M_B \sim -19$ to -19.5) classified in NED as irregular and spiral, respectively, and both show strong Hα emission, with Hα+[NII] equivalent widths of 44 Å and 29 Å respectively. These values are typical for normal late-type spiral and irregular galaxies (Kennicutt & Kent 1983). Both are resolved into bright H II regions with luminosities (above our detection limit) of order $10^{38} - 10^{39}$ ergs s^{-1}, comparable to giant H II regions in the Local group and again quite typical for late-type spiral and irregular galaxies of these masses. Although most of these H II regions lie well within the optical confines of their parent galaxies (e.g., CGCG 97-114*c*, CGCG 97-125*d* and *c* in Figure 4), several bright and very compact knots lie well outside the optical disks (e.g., knots *a* and *b* in both galaxies), and it is not clear whether they are bound to parent galaxies or are separate objects (or satellites).

CGCG 97-125 and CGCG 97-114 both show peculiar morphologies in the Hα images, as is best seen in Figure 2. The broadband images of CGCG 97-125 show the presence of a faint, diffuse shell-like feature, which is characteristic of dynamically disturbed galaxies or merger remnants (e.g., Malin & Carter 1983, Schweizer & Seitzer 1988). The broadband and Hα images reveal a faint tail or bridge-like feature extending to the west of CGCG 97-125, along with a faint arm of H II knots (K2 in Fig. 2) between the two galaxies. These hint at a possible tidal bridge, but the detected features are too faint and discontinuous to indicate this for certain. Neither of the other cataloged galaxies (CGCG 97-113, A1367[BO85]121) show detectable Hα emission, apart from possible low-level nuclear emission. Finally, some of the HII regions in the vicinity of Zwicky galaxies, such as CGCG 97-114*a* and *b* appear almost isolated, not physically associated with the galaxy; there is no obvious underlying stellar distribution, even on our deep broadband image.

3.2.2. Dwarf Galaxies

The three dwarf galaxies Dw1, Dw2, and Dw3 (Table 2, Figure 4) were virtually invisible on the original continuum images taken using the MOSAIC camera, but they were clearly identified in our follow-up deep broadband imaging. All of them display highly irregular and possibly disturbed structures.

$Dw1$ consists of several luminous H II regions in the original MOSAIC images, but the broadband images show that these reside within a somewhat more diffuse structure of blue stars. The B-band magnitude of 18.5 corresponds to an absolute magnitude $M_B = -16.5$ for an assumed distance modulus of 34.84 mag (Sakai et al. 2000). This is roughly comparable to the Small Magellanic Cloud, for example, but the stellar structure is less concentrated and more chaotic in appearance. The galaxy also is unusually blue, with $B-R = 0.05 \pm 0.07$ mag.

Dw2 has an even more peculiar morphology. In the deep B-band image (Figure 2 left panel), Dw2 shows a V-shaped diffuse underlying stellar distribution, with one very bright concentration which also shows Hα-emission. It could be tidally connected to CGCG 97-125 (and possibly to Dw3), but the proximity to NGC 3860 is mostly likely a superposition (recall that the radial velocity of the latter is 2600 km s^{-1} lower). The color of Dw2 is also blue, with $B - R = 0.53 \pm 0.14$ (Table 2).

Dw3 is the faintest of the three newly identified dwarf irregular galaxies ($M_B = -15.8$). Its structure is similar to that of Dw1, with a diffuse distribution of stars connecting the younger H II regions, and no evidence of a central concentration in B or R. It again is extremely blue, with $B - R = 0.20 \pm 0.21$.

3.2.3. Isolated H II Galaxies and H II Regions

Over a dozen of the emission regions in the group do not show any obvious association with any of galaxies, either the luminous CGCG galaxies or the fainter dwarfs described above. It is conceivable that one or two could be very distant background galaxies with [OIII]λ5007 or [OII]λ3727 lines redshifted into the Hα bandpasses, but all of the knots measured spectroscopically to date have radial velocities placing them in this group (§3.4). Several of the knots may lie in the outer extended disks or halos of CGCG 97-114 or 97-125, but the disturbed structure of those objects makes an unambigouous association impossible. Several other knots (e.g., K2 a, b in Figure 4, and a string of knots extending to the northwest of Dw1) appear to be physically related, and may be parts of tidal features extending from the larger galaxies. Finally a few objects (a notable example is K1 in Figure 4) appear to be truly isolated H II regions.

Photometry of the deep broadband images reveals a detected stellar component in almost all of these knots, with typical magnitudes in the range $B \sim R \sim 21 - 23$, or absolute magnitudes in the range -11 to -13, comparable to those of luminous stellar associations in normal spiral and irregular galaxies or the faintest dwarf irregular galaxies. However these knots are distinguished by their compactness and their strong line emission (next section), which are more typical of disk H II regions than of dwarf galaxies.

3.3. Star Formation Rates and Properties

The star formation regions are scattered throughout this area of radius ∼50 kpc, most of which are found in galaxies showing faint, underlying distribution of stars, and are very compact. For example, Dw1 is comprised of six very compact Hα regions as seen in Figure 2. Dw3 has a very similar appearance.

The two CGCG galaxies and the three dwarf galaxies are large and bright enough so that we can measure reliable emission-line fluxes, equivalent widths (EWs), and star formation rates (SFRs). These are listed in Table 3. Iglesias-Paramo et al. (2002) have also reported fluxes and equivalent widths for three of these galaxies (CGCG 97-114, CGCG 97-125, and Dw1) and the values are in excellent agreement with our measurements. The emission-line properties of the two CGCG galaxies also have been discussed previously by Gavazzi et al. (1998) and Moss & Whittle (1998).

As mentioned previously the Hα EWs of CGCG 97-114 and CGCG 97-125 are typical of actively star-forming spiral or Magellanic irregular galaxies. The dwarf Dw1 is much more active, with EW(Hα+[NII]) = 101 ± 4 Å. This high EW requires a current SFR that is several times higher than the time-averaged past SFR in the galaxy, and is comparable to some of the most extreme starburst galaxies in the Galactic neighborhood. Dw3 also has a relatively high SFR. While Dw1 and Dw3 are characterized by clusters of very compact HII regions, Dw2 shows a much more diffuse and fainter Hα distribution. Its very blue color however suggests that it is being observed within 10^8 yr of a recent starburst, or it is experiencing a short-term lull between bursts.

As alluded to earlier, the isolated H II region knots show much stronger emission, with EWs in the range 200 − 400 Å. The only local galaxies with such strong line emission are extreme dwarf starburst galaxies such as I Zw 18 or II Zw 40 (e.g., Martin 1998), but those galaxies also are at least 10 times more luminous in Hα than the knots observed here. The knots more closely resemble in EW, luminosity, and continuum color (as best as can be determined) those of ordinary H II regions in nearby galaxies, or for that matter the individual H II region knots in the CGCG galaxies and dwarf galaxies in this region. Where they differ is in the lack of an obvious association with a parent galaxy (apart for the handful of regions in the very outer disks of CGCG 97-114 and 97-125).

The luminosities of the individual H II regions, whether isolated or within larger parent galaxies, range from a few times 10^{-17} ergs cm^{-2} s^{-1} (the effective faint limit of our data) to $1-2\times10^{-15}$ ergs cm^{-2} s^{-1}. The corresponding Hα+[NII] luminosity range is of order $10^{37}-10^{39}$ ergs s^{-1}. This range extends from analogs of large Galactic H II region complexes (e.g., M17, Carina) to giant H II regions such as NGC 3603 in the Galaxy or NGC 604 in M33 (e.g., Kennicutt 1984). Virtually all of the regions are unresolved or semi-resolved in our images, not suprising given our typical linear resolution of $\sim$500 pc. Although the distributions of star forming regions are irregular and/or disturbed in nearly all of the galaxies, the physical properties of the H II regions themselves do not appear to be unusual in any discernable way.

3.4. Radial Velocities

Table 4 lists the positions and radial velocities of the knots that were measured spectroscopically. All but one of the detected H II regions have radial velocities within a narrow range, 8050 – 8300 km s^{-1}. These correspond to the velocities of the brighter galaxies CGCG 97-114 (8450 km s^{-1}; Falco et al. 1999) and CGCG 97-125 (8271 km s^{-1}; Haynes et al. 1997). This confirms the physical association of the the dwarf galaxies and knots with this group, and rules out any association with NGC 3860 or the possibility that these are superimposed objects near the central velocity of A1367 itself (6600 km s^{-1}). It is very likely that most or all of the emission knots in Figures 2 and 4 are also associated with this system. Although we do not have spectroscopic velocities for the other knots, their emission-line flux ratios in the Ha16 and Ha12 MOSAIC images (with central velocities of 6723 Å and 6683 Å respectively) are similar to those of the H II regions in Table 4, and this restricts the velocity range to approximately 8200 $\pm$ 500 km s^{-1}.

In table 4 we also list the radial velocities measured from the WSRT HI line observations, or when the WSRT resolution does not permit a precise velocity measurement, the range of velocities observed at the position of the optical pointings. The agreement is in general quite good and within the mutual uncertainties, further confirming the association of the emission knots with the galaxies CGCG 97-114 and CGCG 97-125. In Dw 3, no HI was detected to a 3σ limit of 1.3×10^{8} M$_{\odot}$.

3.5. Emission-Line Spectra and Metal Abundances

For five of the emission regions (Dw 1-a, Dw 1-b, Dw 3-a, CGCG 97-114-b, K2-a), our spectra are of sufficient quality to constrain the emission properties and metal abundances. In addition, we obtained spectra of three H II regions in the southern spiral arm of CGCG 97-125 for comparison. We only analyzed spectra with S/N $>$ 10 in all of the diagnostic lines Hα, Hβ, [OII]λ3727, [OIII]λ5007, and [NII]λ6583. For most of the H II regions the Balmer decrement is sufficiently well measured to provide a robust reddening corrections for the spectra, using the reddening curve of Cardelli, Clayton, & Mathis (1989). However in the faintest objects (K2-a, Dw 3-b), the reddening determination was very uncertain, either due to the signal/noise in the Hβ line or from the presence of strong underlying stellar Hβ absorption (which we corrected for using a standard absorption EW of 3 Å). In these latter cases we normalized the forbidden line ratios to Hα, with an assumed Hα/Hβ ratio of 3.0. To confirm the reliability of the data we obtained spectra of Dw 1-a, b and the CGCG 97-125 H II regions at much higher quality with the MMT telescope (§2), and these yield consistent results (see Figure 5). Nevertheless we will restrict most of our analysis to the reddening-insensitive [OIII]/Hβ and [NII]/Hα ratios, and use empirical abundance indices (which are more sensitive to the reddening correction) only to roughly characterize the abundance ranges for the objects.

The left panel of Figure 6 shows the excitation properties of the H II regions in the familar plot of [OIII]/Hβ vs [NII]/Hα introduced by Baldwin, Phillips, & Terlevich (1981). The A1367 H II regions are plotted as large symbols, while the small points represent the samples of nearby H II regions in spiral galaxies from McCall, Rybski, & Shields (1985) and H II regions in M101 from Kennicutt & Garnett (1996). Most of the emission regions in this group fall along the standard emission-line for stellar-photoionized H II regions. The main locus of points appears to lie slightly to the right of the main excitation sequence. This could be caused by any number of factors, including an enhanced N/O abundance ratio, contamination of the spectrum by shocked gas (e.g., Kewley et al. 2001), or by excess stellar absorption at Hβ, which would artificially elevate the measured [OIII]/Hβ ratio. In the few cases where our spectra extend to [SII]$\lambda\lambda$6717,6731 we see no evidence of enhanced [SII], which would be expected if the gas were shocked. Otherwise our spectra are not of sufficient quality to distinguish between those possibilities, but in any case the objects appear to be normal stellar-ionized H II regions.

We also have used the abundance-sensitive empirial ratios $R_{23} \equiv ([\mathrm{OII}]\lambda3727 + [\mathrm{OIII}]\lambda4959{,}5007)/\mathrm{H}\beta$ (Edmunds & Pagel 1984) and [NII]λ6583/[OII]λ3727 (Kewley et al. 2002) to place crude constraints on the metal abundances in the regions. The right panel of Figure 6 plots the positions of the A1367 knots and the comparison H II regions in a diagram with the logarithms of R_{23} on the horizontal axis and [NII]/[OII] on the vertical axis. As shown in Kennicutt & Garnett (1996), the two indices form a relatively tight abundance sequence in normal galaxies, and the A1367 H II regions appear to fall along the same locus, although a few objects appear to lie somewhat higher than the mean relation for spiral galaxies and M101. A conservative estimate of the observational errors is indicated by the spread of values for CGCG 97-125 (open squares in Figure 6), which include multiple measurements of some of the same H II regions. The corresponding uncertainty in absolute abundances is as much as ±0.2 dex, including an uncertainty of ±0.1–0.15 in the zeropoint of the abundance calibration of the indices in this range (e.g., Kewley et al. 2002). Nevertheless this still allows us to draw some important conclusions about the metal abundances and physical nature of the emission regions.

The H II regions in this group are surprisingly metal-rich. If we apply the calibrations of Kewley et al. (2002) the range of R_{23} and [NII]/[OII] values for the H II regions correspond to oxygen abundances of $12+\log(O/H) = 8.3-8.9$, or $0.25 - 1.0$ $(\mathrm{O/H})_{\odot}$. Other calibrations of the line indices give a similar abundance range. The H II regions in the bright galaxy CGCG 97-125 lie at the high end of this range, at solar abundance $(12 + \log(O/H) = 8.9 \pm 0.2$

The most metal-poor regions are those in the isolated dwarf galaxies Dw 1 and Dw 3 (large open and filled circles in Figure 6, respectively). Normal field irregular and spiral galaxies exhibit a pronounced metallicity-lumninosity relation (e.g., Skillman, Kennicutt, & Hodge 1989, Zaritsky, Kennicutt, & Huchra 1994), and if these dwarf galaxies have evolved chemically independent of their environment we would expect their abundances and luminosities to lie on this correlation. For the Skillman et al. (1989) relation galaxies in this luminosity range ($M_B = -15.8$ to -16.5) have a typical oxygen abundance of $12+\log(O/H) = 8.0\pm0.3$. Dw 1 and Dw 3 appear to be more metal rich than this mean by about a factor of two in O/H, but this difference is marginally significant given the accuracy of the abundance measurements, the dispersion in the metallicity-luminosity relation, and a possible offset between the R_{23} and [NII]/[OII] index calibrations of Kewley et al. (2000) and the electron-temperature based scale of Skillman et al. (1989).

The abundances of the faint isolated knots K2-a and K2-b are completely anomalous, however. Their forbidden-line spectra (crosses in Figure 6) correspond to abundances in the range 0.5 - 1.0 $(\mathrm{O/H})_{\odot}$. If these knots were isolated H II galaxies we would expect their abundances to be in the range 1/40 – 1/20 solar! Instead their metal abundances are comparable to those of CGCG 97-125 (which is consistent with the normal metallicity-luminosity relation of Zaritsky et al. 1994). These observed abundances immediately rule out any evolutionary scenario in which the intergalactic knots K2 are isolated, normal dwarf galaxies evolving as closed systems. The high abundances probably also rule out a picture in which the K2 knots condensed out of intergalactic gas in A1367. Instead, the high metallicities, and their similarity to the compositions of the H II regions in CGCG 97-125 favor a picture in which the K2 knots formed from enriched material stripped from one of the larger galaxies, perhaps in a recent tidal interaction. The suggestion of a tidal arm of H II regions connecting CGCG 97-125 and CGCG 97-114 mentioned earlier (see Figure 4) would be consistent with this interpretation.

3.6. HI Aperture Synthesis Imaging

The integrated HI column density image of this group of galaxies is shown in Figure 7 as an overlay on the blue Digital Sky Survey.[5] CGCG 97-125 is clearly detected and has an HI mass of 3.9×10^9 $M_\odot$. Also CGCG 97-114 (NGC 3860b) is detected, albeit at a much lower level, and has a measured HI mass of 3.0×10^8 $M_\odot$. The corresponding M_{HI}/L_B ratios are 0.31 (0.49 if we include the extended HI features joining Dw 2 and K2 with CGCG 97-125) and 0.03 respectively. These are typical values for Sc-Sd and E/S0 galaxies, respectively (Roberts & Haynes 1994). This implies that CGCG 97-114 is somewhat gas poor for its Hubble type (Sa, Haynes et al. 1999) by a factor of ~ 5: only a quarter of the Sa galaxies have M_{HI}/L_B values below 0.03 (Roberts & Haynes 1994). CGCG 97-125 on the other hand has a normal gas content for its Hubble type (Sc, Haynes et al. 1999).

The relatively high SFR in CGCG 97-125 is consistent with its large HI content, but the even higher SFR in CGCG 97-114 is surprising in terms of its low HI mass. At its current SFR of at least $0.7 - 2$ $M_\odot$ yr^{-1} (depending on the extinction correction for Hα, which is uncertain), the total HI mass of CGCG 97-114 would be depleted in $\sim 2 - 5 \times 10^8$ years. Boselli et al. (1997) detected CO emission in this galaxy, corresponding to a total molecular gas mass of 4×10^8 $M_\odot$. Including this gas doubles the depletion time, but it still is well under a Gyr. This suggests that the galaxy is currently experiencing an intense, transient burst of star formation.

In addition to the two detected CGCG galaxies there appears to be extended HI, mostly around CGCG 97-125. The brightest extension is to the south-west, reaching peak column density levels of 2×10^{20} cm^{-2}, containing 1.6×10^9 $M_\odot$. On deep exposures one can see that CGCG 97-125 has optical extensions in this direction, though not reaching as far as

[5]The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAGW-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

the HI extension. The HI extension appears to be a continuation of the Hα structure to the west of CGCG 97-125. This extended structure is typical of galactic merger remnants (e.g., Hibbard & van Gorkom 1997), and reinforces the evidence from the optical morphology of CGCG 97-125 for a recent merger event in this galaxy.

To the north-west of CGCG 97-125 another HI extension is found, reaching column density levels of 10^{20} cm^{-2}, containing 6.4×10^8 M$_\odot$. Part of this HI extension coincides with the position of the dwarf galaxy Dw 2 in Figure 4. It is notable that HI gas is *not* detected unambiguously in the other dwarfs Dw 1 or Dw 3, though any emission from Dw 1 might be confused with gas in CGCG 97-125 (the WSRT beam is most extended in the N-S direction connecting the two objects). If these galaxies had normal HI contents, we would expect them to have gas masses of order 10^8 M$_\odot$, which would be near or just below the 3σ detection limit of the present observations.

The presence of a prominent HI bridge is the strongest evidence for strong tidal interactions in the CGCG 97-114/125 group. As observed in Figure 7, this bridge extends through many of the emission regions discussed in this paper, from CGCG 97-125 itself (and possibly Dw 1) through the bright H II regions to the SW of the galaxy, the knots K2-a, b, and north through the dwarf galaxy Dw 2. The HI distribution which is not confined to the vicinity of a galaxy as observed here is reminiscent of other examples of interacting galaxies, such as the M81-M82-N3077 group (Yun, Ho, & Lo 1994). It is significant however that there is no evidence of a tidal bridge connecting the two brightest members of the group, CGCG 97-125 and CGCG 97-114.

The HI distribution around CGCG 97-125 is extended not only in the plane of the sky, but in the velocity dimension as well. A position-velocity diagram centered on CGCG 97-125 is shown in Figure 8. The velocity distribution shows a regular gradient accross the galaxy (the optical major axis of CGCG 97-125 is very close to E/W) ranging from 8090 up to 8490 km/s. If this reflects the rotation of the disk, it means a projected rotation speed of 200 km s^{-1}, or $\sim$ 340 km s^{-1} when corrected for an inclination of 36° (Haynes et al. 1999). This is exceptionally high for a $M_B = -19.1$ galaxy, which usually has a rotation speed of $\sim$ 200 km s^{-1} (Broeils 1992, Verheijen 1997). We do not have sufficient resolution to fully resolve the velocity field of the HI surrounding CGCG 97-125, so it is conceivable that some of the gas is not part of the disk of CGCG 97-125 and has very peculiar velocities. In summary, both the HI distribution and the HI kinematics of CGCG 97-125 are quite peculiar.

The velocity structure to the west of CGCG 97-125 reflects the complex kinematics of the extended HI towards the region K2. This gas blends in with the gas in CGCG 97-125 at a velocity of 8230 km s^{-1} and shows a regular velocity gradient down to 8060 km s^{-1} at the position of K2. The HI to the north-west of CGCG 97-125 (associated with Dw 2) has a velocity of 8140 km s^{-1}.

4. DISCUSSION

At the outset of this analysis we considered three physical explanations for this unusual group of galaxies:

1) The CGCG 97-114/125 group is a normal compact group of field galaxies observed in projection behind A1367; it is nothing more than a usual collection of spiral and irregular galaxies which happen to be actively forming stars at approximately the same time.

2) The unusual star formation properties of the group are the result of a strong interaction with the intergalactic medium in A1367, caused by shocking of the ISM as these galaxies move through the IGM with an encounter velocity of 1600 km s^{-1}.

3) The unusual star formation properties of the group are caused by current and/or past tidal encounters between two or more of the galaxies in the group, largely independent of the cluster environment outside of the group.

Our follow-up deep imaging, spectroscopic observations, and HI data appear to strongly favor the last of these interpretations, but we first summarize the evidence against the other scenarios. While it is certainly true that many normal galaxy groups contain as many as several strongly star-forming dwarf galaxies, the concentration of so many starbursting dwarf galaxies and H II galaxies in such a small region ($\sim$100 kpc) is very unusual, apart from groups containing strongly interacting galaxies. We would expect to find far more quiescent dwarf galaxies in the region if the starbursts we observe were not triggered by a common physical mechanism. Moreover, the high metal abundances of intergalactic knots and the HI tails/bridges provide direct evidence for the importance of tidal processes.

Induced star formation from IGM interactions is not quite as easily ruled out, especially because evidence for such processes is found elsewhere in A1367 (Gavazzi et al. 1995). However this interpretation appears to be unlikely on a number of grounds. None of the galaxies in the CGCG 97-114/125 group show evidence of the bow-shock structure in the Hα or broadband images, or asymmetric HI distributions that is characteristic of the other objects of this type in A1367 and elsewhere. And perhaps more significantly, we would expect a 1600 km s^{-1} encounter between the galaxy ISMs and the A1367 IGM to produce copious soft X-ray emission, but Chandra maps of this region do not show evidence of this type of extended emission (Sun et al. 2001, Sun & Murray 2002).

Instead, several lines of evidence point to the liklihood that the unusual star formation properties of this group are triggered by one or more major tidal interactions within the CGCG 97-114/125 group. To summarize they include: 1) morphological evidence for disturbed dynamical structure of CGCG 97-125 and 97-114; 2) presence of massive tidal structures connecting many of the emission regions in the HI maps; 3) the low dispersion in radial velocities of the star-forming galaxies and emission knots, including those located outside of the HI features; and 4) near-solar metal abundances in some of the apparently isolated intergalactic H II regions along the HI arm, and suspiciously high abundances in some of the starbursting dwarf galaxies.

The most straightforward interpretation of these observations is that the largest galaxy in the group, CGCG 97-125, has undergone at least one major tidal encounter with other members of the group, including a recent merger event that has produced its shell-like outer structure. These interactions have pulled metal-rich gas out of the galaxy, into an extended tidal tail or arm, and some of the gas has collapsed to form H II regions or tidal dwarf galaxies in the HI arms.

Similar structures and star-forming regions are observed in some nearby examples of interacting galaxy pairs and merger remnants. Perhaps the closest analog is the Antennae system NGC 4038/9, which exhibits extended HI arms (Hibbard et al. 2001) with similar HI masses and a series of massive star-forming knots that have been proposed to be newly-formed tidal dwarf galaxies (Mirabel, Dottori, & Lutz 1992, Braine et al. 2001). Tidal dwarf galaxy formation also has been purported to be occurring in the gaseous arms of other nearby interacting galaxies (e.g., Duc & Mirabel 1998, Weilbacher et al. 2000, Braine et al. 2001). The morphology of the faint knots observed in the CGCG 97-114/125 group bear some resemblance to these systems, particularly in HI, but the main difference is the absence of continuous stellar counterparts to the HI arms; here the H II regions are fainter and more isolated. This might be explained if the tidal features in this group are older, and gravitationally unbound from parent galaxies already, or if the efficiency of star formation in these interactions were much lower for some reason.

The origin of the larger dwarf galaxies Dw 1, Dw 2, and Dw 3 is less clear. The unusually blue colors and faint, diffuse underlying stellar components in these galaxies tempts us to speculate that these objects too may have been formed relatively recently (e.g., last 1–2 Gyr) in tidal interactions. However the observed metal abundances of Dw 1 and Dw 3 are plausibly consistent with their being old irregular galaxies that have evolved independently. Some qualities that characterize tidal dwarf galaxies include the lack of dark matter and a small fraction of old stellar population (Hunter, Hunsberger & Roye 2000). Deeper imaging (at visible and near-infrared wavelengths) and measurements of the stellar kinematics, or HI rotational velocity would be able to discern the presence of an older stellar population, if any, and test whether these objects contain the dark matter halos expected for normal dwarf irregular galaxies. We may have found an example of a very recent interaction in which the disk of one of the galaxies (CGCG 97-114 with its low M_{HI}/L_B) was severely disrupted by a much more massive object (CGCG 97-125), leaving the shreds of the outer disk behind, which we are now witnessing as small star-forming regions.

It is intriguing to speculate on the eventual fate of the metal-rich H II regions (e.g., K2). These objects almost certainly are newly formed from the tidal debris of the galaxy interactions in this group, but it is unclear whether the associated star clusters will remain gravitationally bound to the more massive galaxies or will form new tidal dwarf galaxies. Again, more accurate kinematic observations of the knots and the other galaxies in the region should allow one to fit a dynamical model to the HI and optical observations, and constrain not only the orbits of the knots but also the mass distributions in the halo of CGCG 97-125 and 97-114.

We also draw attention to the possible connection between these types of objects and the isolated compact dwarf galaxies that have recently been discovered in the Fornax cluster by Drinkwater et al. (2001) and Phillips et al. (2001). The latter objects appear to be either tidally stripped remnants of dwarf galaxies or massive isolated star clusters. It is conceivable that some of the star-forming regions observed in the CGCG 97-114/125 group may evolve into isolated intergalactic dwarf galaxies or star clusters in A1367, though it appears that the precursors to the massive objects observed in Fornax probably were considerably more massive than the regions we have observed here.

Finally we remark briefly on the the apparent rarity of groups of this kind in nearby galaxy clusters. No other comparable subgroups or subclusters of star-forming regions have been found elsewhere in our Abell cluster survey, which covers 25 square degrees and a search volume of approximately 300 Mpc^3 in 8 clusters. This may not be entirely surprising, because if the star formation observed in this group has been triggered by tidal encounters it requires low-velocity interactions of order a few hundred km s^{-1} or less, which is much lower than the typical encounter velocities in these rich Abell clusters.

These considerations suggest instead that compact groups may be the most prolific environment for this mode of star and galaxy formation. A deep Hα imaging survey of compact groups by Iglesias-Paramo & Vilchez (2001) has revealed tidally extended star-forming regions in 5 of 16 groups surveyed. These H II regions probably are the closest analogs to the objects studied in this paper, though most of the emission knots found in the survey of Iglesias-Paramo & Vílchez (2001) lie on well-defined tidal arms of large galaxies, or on well-defined tidal bridges connecting the interacting galaxies. Perhaps deep imaging of other compact groups will reveal closer analogs to the concentration of star-forming galaxies in the CGCG 97-114/125 group. Until then this remarkable region appears to be unique.

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Table 1. WSRT Observing Parameters

Dates of observation	13 May 2001, 8 September 2001
Pointing Center (J2000)	11:44:50.0 19:47:0.0
Central Velocity (heliocentric)	8300 km s^{-1}
Velocity Range	7220 - 9205 km s^{-1}
Velocity Resolution	20.9 km s^{-1}
Sensitivity	0.4 mJy/beam
Resolution (ra x dec)	18” x 50”
Brightness sensitivity	0.25 K

Table 2. Galaxies in the CGCG 97-113/114/125 Group

Galaxy	RA (J2000)	DEC (J2000)	B (mag)	R (mag)
CGCG 97-114	11:44:47.8	19:46:24	15.70 ± 0.03	14.92 ± 0.03
CGCG 97-125	11:44:54.8	19:46:35	15.37 ± 0.03	14.03 ± 0.03
Dw1	11:44:54.2	19:47:16	18.35 ± 0.05	18.30 ± 0.05
Dw2	11:44:51.3	19:47:16	18.72 ± 0.10	18.19 ± 0.10
Dw3	11:44:46.0	19:47:40	19.09 ± 0.15	18.89 ± 0.15

Table 3. Star Formation Rates of Hα-emitting galaxies

Galaxy	Flux (erg cm^{-2} s^{-1})	L(Hα) (10^{41} erg s^{-1})	SFR[1] ((M$_\odot$/yr)	Observed EW ($\AA$)
CGCG 97-114	6.33 ($\pm$0.06) $\times$ 10^{-14}	0.66	0.59	44 $\pm$ 3
CGCG 97-125	9.51 ($\pm$0.06) $\times$ 10^{-14}	0.99	0.88	29 $\pm$ 3
Dw1	8.67 ($\pm$0.19) $\times$ 10^{-15}	0.09	0.08	101 $\pm$ 4
Dw2	7.81 ($\pm$1.59) $\times$ 10^{-16}	0.01	0.01	16 $\pm$ 4
Dw3	2.88 ($\pm$0.15) $\times$ 10^{-15}	0.03	0.03	45 $\pm$ 3

[1]Star formation rates derived using the calibration of Kennicutt (1998), without any correction for extinction in the galaxies.

Table 4. Spectroscopic Data

Knots	Position (RA & DEC)		Heliocentric Velocity (km s^{-1})	HI velocity (km s^{-1})
CGCG 97-114-b	11:44:46.36	19:46:41.4	8504 $\pm$ 50	8474
CGCG 97-125-b	11:44:54.66	19:46:11.5	8170 $\pm$ 50	8250
Dw 1-a	11:44:54.61	19:47:32.5	8161 $\pm$ 50	8140-8230
Dw 1-b	11:44:53.74	19:47:31.2	8070 $\pm$ 50	8140-8230
Dw 3-a	11:44:46.39	19:47:40.6	8266 $\pm$ 50	
Dw 3-b	11:44:45.49	19:47:45.5	8289 $\pm$ 50	
K2-a	11:44:50.61	19:46:02.4	8099 $\pm$ 50	8091
K2-b	11:44:49.61	19:46:04.0	8053 $\pm$ 50	8091

Figure Captions:

Figure 1: Broadband images of the CGCG 97-113/114/125 group. At the distance of 93Mpc, 1 arcmin corresponds to 27Kpc

Figure 2: A continuum-subtracted Hα image of the region around NGC 3860 in Abell 1367. See Figure 4 for identifications of galaxies and emission-line regions. Note that the bright object near $K2$ (Fig 4) is a foreground stars

Figure 3: *Lower left:* The distribution fo galaxies in Abell 1367 in the plane of sky. The position of the CGCG 97-113/114/125 group is indicated by an open circle. Also shown are the distributions of A1367 galaxies in the velocity-declination plane *(lower right)* and in the right ascension-velocity plane.

Figure 4: A Hα + [NII] + continuum image. Dwarf galaxies and HII regions detected in this paper are shown.

Figure 5: Spectrum of Knot a in the dwarf galaxy Dw 1, obtained with the Blue Channel spectrograph on the 6.5 m MMT telescope.

Figure 6: Spectroscopic properties of selected HII regions in the CGCG 97-114/125 group. (Left): Correlation between the reddening-insensitive [OIII]/Hβ and [NII]/Hα excitation indices. Regions in the group are marked as large symbols. The small points are comparision HII regions in nearby galaxies, as described in the text. (Right): Distribution of the abundance-sensitive R23 and [NII]/[OII] ratios, as discussed in the text.

Figure 7: HI column density distribution in the CGCG 97-114/25 group overlaid on the XDSS blue image. Contours are 0.5, 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 $\times 10^{20}$ cm^{-2}. The angular resolution is $18'' \times 50''$(R.A. $\times$ Dec).

Figure 8: HI Position-velocity diagram (position angle 90 degrees) centered on CGCG 97-125. Contours are -0.7, -0.35, 0.35, 0.7, 1.4, 2.1, 2.8, 3.5 and 4.2 mJy. Negative contours are dashed.